ANNEX G

Methodology for Estimating CH_4 Emissions from Natural Gas Systems

The following steps were used to estimate methane emissions from natural gas systems.

Step 1: Calculate Emission Estimates for Base Year 1992 Using GRI/EPA Study

The first step in estimating methane emissions from natural gas systems was to develop a detailed base year estimate of emissions. The study by GRI/EPA (1996) divides the industry into four stages to construct a detailed emission inventory for the year 1992. These stages include: field production, processing, transmission and storage (i.e., both underground and liquefied gas storage), and distribution. This study produced emission factors and activity data for over 100 different emission sources within the natural gas system. Emissions for 1992 were estimated by multiplying activity levels by emission factors for each system component and then summing by stage. Since publication, the EPA has updated activity data for some of the components in the system. Table G-1 displays the 1992 GRI/EPA activity levels and emission factors for venting and flaring from the field production stage, and the current EPA activity levels and emission factors. These data are shown to illustrate the kind of data used to calculate emissions from all stages.

Step 2: Collect Aggregate Statistics on Main Driver Variables

As detailed data on each of the over 100 sources were not available for the period 1990 through 2001, activity levels were estimated using aggregate statistics on key drivers, including: number of producing wells (API 2002, EIA 2002d), number of gas plants (AGA 1990 through 1998; OGJ 1999 through 2002), miles of transmission pipeline (OPS 2002a), miles of distribution pipeline (OPS 2002b), miles of distribution services (OPS 2002b), energy consumption (EIA 2001, 2002c, 2002f). Data on the distribution of gas mains and services by material type was not available for 1990 through 1992 from OPS. For those years, the distribution by type was back calculated from 1993 using compound growth rates determined for the years 1993 through 2000. Table G-2 provides the activity levels of some of the key drivers in the natural gas analysis.

Step 3: Estimate Emission Factor Changes Over Time

In the past, emissions factors were reduced at a rate of 0.2 percent per year such that by year 2020, emissions factors would have declined by 5 percent from 1995. These reductions were made to reflect underlying technological improvements through both innovation and normal replacement of equipment. However, the analysis already incorporates the emissions reductions from some of these technological improvements as reported by EPA's Natural Gas STAR Partners. Thus, to eliminate this double counting, the emissions factors were kept constant throughout the time series for this year's Inventory.

Step 4: Estimate Emissions for Each Year and Stage

Emissions from each stage of the natural gas industry were estimated by multiplying the activity factors by the appropriate emission factors, summing all sources for each stage, and then subtracting the Natural Gas STAR emission reductions. Methane reductions from the Natural Gas STAR program for the years 1990 through 2000 are presented in Table G-3. Emission reductions by project are reported by industry partners using actual measurement data or equipment-specific emission factors. Before incorporating the reductions into the Inventory, quality assurance and quality control checks are undertaken to identify errors, inconsistencies, or irregular data. Total emissions were estimated by adding the emission estimates from each stage. Table G-4 illustrates emission estimates for venting and flaring emissions from the field production stage using this methodology. Table G-5 presents total natural gas production and associated methane emissions.

Table G-1: 1992 Data and Emissions (Mg) for Venting and Flaring from Natural Gas Field Production Stage

Activity	*GRI/EPA Values* Activity Data	Emission Factor	Emissions	*EPA Adjusted Values* Activity Data	Emission Factor	Emissions
Drilling and Well Completion						
Completion Flaring	844 compl/yr	733 Scf/comp	12	400 compl/yr	733 scf/comp	6
Normal Operations						
Pneumatic Device Vents	249,111 controllers	345 Scfd/device	602,291	249,111 controllers	345 scfd/device	602,291
Chemical Injection Pumps	16,971 active pumps	248 Scfd/pump	29,501	16,971 active pumps	248 scfd/pump	29,502
Kimray Pumps	11,050,000 MMscf/yr	368 Scf/MMscf	78,024	7,380,194 MMscf/yr	992 scf/MMscf	140,566
Dehydrator Vents	12,400,000 MMscf/yr	276 Scf/MMscf	65,608	8,200,215 MMscf/yr	276 scf/MMscf	43,387
Compressor Exhaust Vented						
Gas Engines	27,460 MMHPhr	0.24 Scf/HPhr	126,536	27,460 MMHPhr	0.24 scf/HPhr	126,535
Routine Maintenance						
Well Workovers						
Gas Wells	9,392 w.o./yr	2,454 scfy/w.o.	443	9,392 w.o./yr	2,454 scfy/w.o.	443
Well Clean Ups (LP Gas Wells)	114,139 LP gas wells	49,570 scfy/LP well	108,631	114,139 LP gas wells	49,570 scfy/LP well	108,631
Blowdowns						
Vessel BD	255,996 vessels	78 scfy/vessel	383	242,306 vessels	78 scfy/vessel	363
Pipeline BD	340,000 miles (gath)	309 scfy/mile	2,017	340,200 miles (gath)	309 scfy/mile	2,018
Compressor BD	17,112 compressors	3,774 scfy/comp	1,240	17,112 compressors	3,774 scfy/comp	1,240
Compressor Starts	17,112 compressors	8,443 scfy/comp	2,774	17,112 compressors	8,443 scfy/comp	2,774
Upsets						
Pressure Relief Valves	529,440 PRV	34.0 scfy/PRV	346	529,440 PRV	34.0 scfy/PRV	346
ESD	1,115 platforms	256,888 scfy/plat	5,499	1,372 platforms	256,888 scfy/plat	6,767
Mishaps	340,000 miles	669 scfy/mile	4,367	340,200 miles	669 scfy/mile	4,370

Table G-2: Activity Factors for Key Drivers

Variable	Units	1990	1995	1996	1997	1998	1999	2000	2001
Transmission Pipelines Length	miles	291,990	296,947	292,186	294,304	302,706	296,581	293,774	278,269
Wells									
GSAM Appalachia Wells*	# wells	120,443	122,805	122,700	120,037	117,878	118,723	116,702	116,702
GSAM N Central Associated Wells*	# wells	3,780	3,641	3,417	3,409	3,361	2,874	2,439	2,278
GSAM N Central Non-Associated Wells*	# wells	3,277	7,234	7,844	8,910	8,917	8,800	9,113	9,113
GSAM Rest of US Wells*	# wells	145,380	168,502	171,267	182,024	190,134	174,898	180,424	180,424
GSAM Rest of US Associated Wells*	# wells	270,958	264,837	264,807	264,385	254,848	251,686	245,967	244,557
Appalch. + N. Central Non-Assoc. + Rest of US	# wells	269,100	298,541	301,811	310,971	316,929	302,421	306,239	306,239
Platforms									
Gulf of Mexico Off-shore Platforms	# platforms	3,798	3,868	3,846	3,846	3,963	3,975	4,019	4,009
Rest of U.S. (offshore platforms)	# platforms	24	23	24	23	23	23	23	23
N. Central Non-Assoc. + Rest of US Wells	# platforms	148,657	175,736	179,111	190,934	199,051	183,698	189,537	189,537
Gas Plants									
Number of Gas Plants	# gas plants	761	675	623	615	558	581	585	570
Distribution Services									
Steel – Unprotected	# of services	5,500,993	6,151,653	5,775,613	5,518,795	5,463,253	5,751,250	5,676,582	5,855,612
Steel - Protected	# of services	19,916,202	21,002,455	18,593,770	19,078,467	18,478,344	18,310,719	17,775,878	17,828,261
Plastic	# of services	16,269,414	26,044,545	26,187,536	27,800,401	28,629,388	28,796,952	31,644,014	33,144,535
Copper	# of services	1,379,237	1,445,380	1,519,625	1,498,050	1,464,019	1,458,518	1,434,091	1,395,232
Total	# of services	43,065,846	54,644,033	52,076,544	53,895,713	54,035,004	54,317,439	56,530,565	58,223,640
Distribution Mains									
Steel – Unprotected	miles	91,267	94,058	88,412	85,166	86,639	84,534	82,817	81,258
Steel – Protected	miles	491,120	503,288	484,526	479,278	484,963	459,298	468,932	484,451
Cast Iron	miles	52,644	50,625	51,542	47,669	47,587	45,865	44,736	47,443
Plastic	miles	202,269	353,735	350,699	385,373	400,627	415,210	446,554	504,199
Total	miles	837,300	1,001,706	975,179	997,486	1,019,816	1,004,907	1,043,039	1,117,351

* GSAM (Gas Systems Analysis Model) is a natural gas supply, demand, and transportation model used by the Federal Energy Technology Center of the U.S. Department of Energy (GSAM 1997).

Table G-3. Methane reductions from the Natural Gas STAR program (Tg)

Process	1990	1995	1996	1997	1998	1999	2000	2001
Production	.01	0.09	0.17	0.22	0.26	0.29	0.31	0.33
Processing	--	0.00	0.00	0.00	0.02	0.03	0.03	0.03
Transmission and Storage	--	0.12	0.10	0.13	0.18	0.22	0.27	0.34
Distribution	--	0.02	0.02	0.03	0.02	0.02	0.02	0.02

Table G-4: CH_4 Emission Estimates for Venting and Flaring from the Field Production Stage (Mg)

Activity	1990	1995	1996	1997	1998	1999	2000	2001
Drilling and Well Completion								
Completion Flaring	5.5	6.1	6.2	6.4	6.5	6.2	6.3	6.3
Normal Operations								
Pneumatic Device Vents	589,673	697,087	710,474	757,372	789,570	728,669	751,831	751,831
Chemical Injection Pumps	37,761	45,545	46,547	49,768	51,783	47,943	49,476	49,476
Kimray Pumps	137,344	152,210	153,856	158,434	161,408	154,106	156,002	156,002
Dehydrator Vents	42,392	46,981	47,489	48,902	49,820	47,566	48,151	48,151
Compressor Exhaust Vented Gas Engines	123,884	146,451	149,263	159,116	165,881	153,086	157,952	157,952
Routine Maintenance								
Well Workovers Gas Wells	543	602	609	627	639	610	617	617
Well Clean Ups (LP Gas Wells)	103,451	114,649	115,888	119,337	121,577	116,076	117,505	117,505
Blowdowns								
Vessel BD	265	307	312	329	340	318	326	326
Pipeline BD	1,749	1,918	1,938	2,005	2,052	1,956	1,988	1,988
Compressor BD	1,598	1,816	1,840	1,927	1,988	1,860	1,900	1,899
Compressor Starts	3,575	4,062	4,116	4,311	4,448	4,162	4,250	4,249
Upsets								
Pressure Relief Valves	338	400	408	435	453	418	431	431
ESD	6,764	6,882	6,848	6,843	7,048	7,069	7,146	7,129
Mishaps	947	1,038	1,049	1,085	1,111	1,058	1,076	1,076

Table G-5: U.S. Total Natural Gas Production (Trillion Ft^3/yr) and Associated CH_4 Emissions (Gg)

Activity	1990	1995	1996	1997	1998	1999	2000	2001
Production	17.8	18.6	18.9	18.9	19.0	18.8	19.0	19.4
CH_4 Emissions from Production	1,445	1,583	1,537	1,577	1,605	1,463	1,488	1,467